ARPA-E Perform Workshop

Operational Challenges and Potential Opportunities Transitioning to a Low Carbon Grid

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W Hotel – Union square
New York
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California is aggressively pursuing a low carbon future

- Aggressive renewable energy goals

33% by 2020 → 60% by 2030 → 100% zero-carbon by 2045

- Deep greenhouse gas (GHG) reduction goals

2020 Target	2030 Target	2050 Target
Reduce GHG emissions to 1990 levels	40% below 1990 levels	80% below 1990 levels

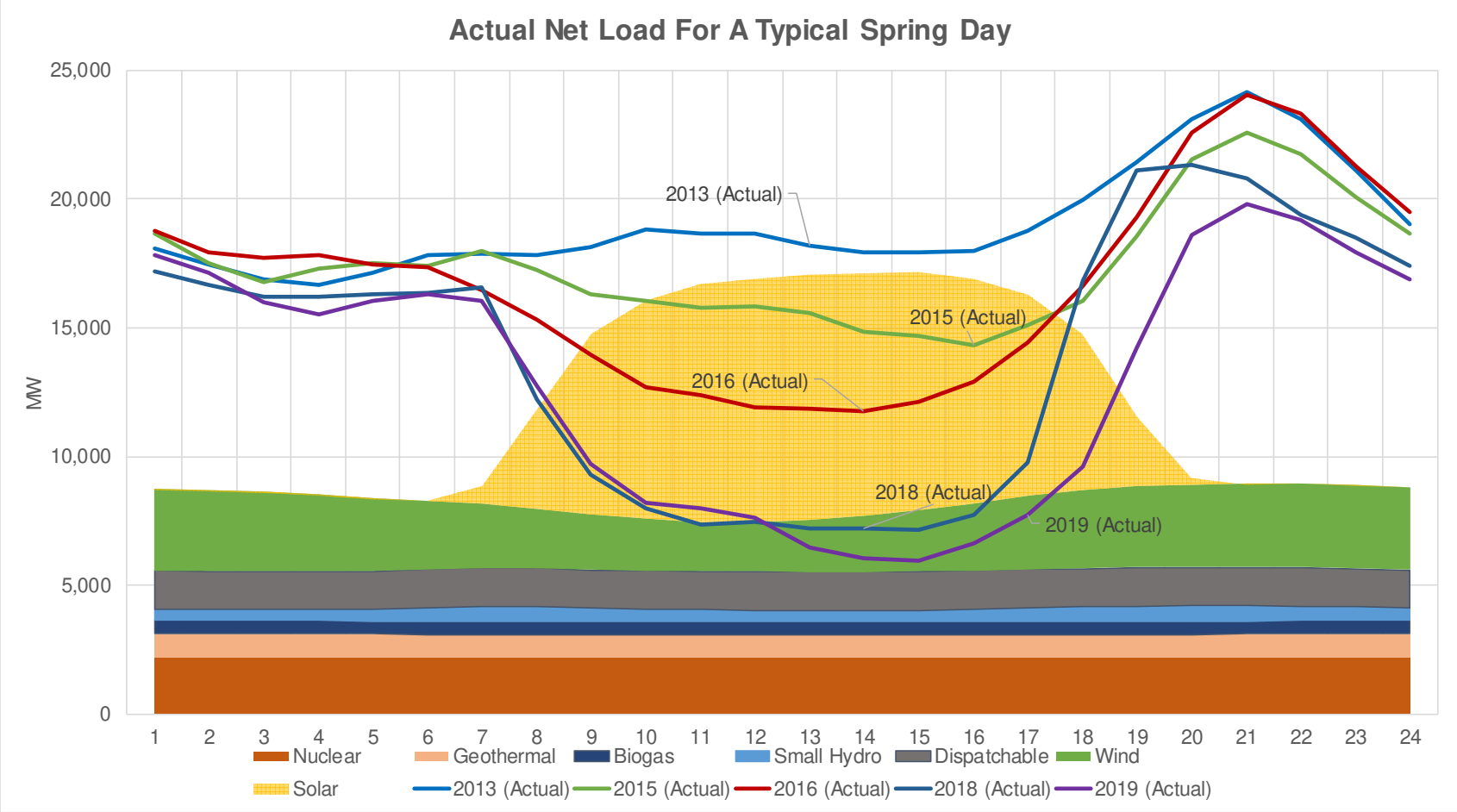
- Robust electric vehicles goal: 1.5 million by 2025
- 12,000 MW of distributed generation by 2020;
- 1.3 GW of battery storage by 2024

→ **Decarbonization is creating opportunities to develop a high renewables and high DER energy service industry**

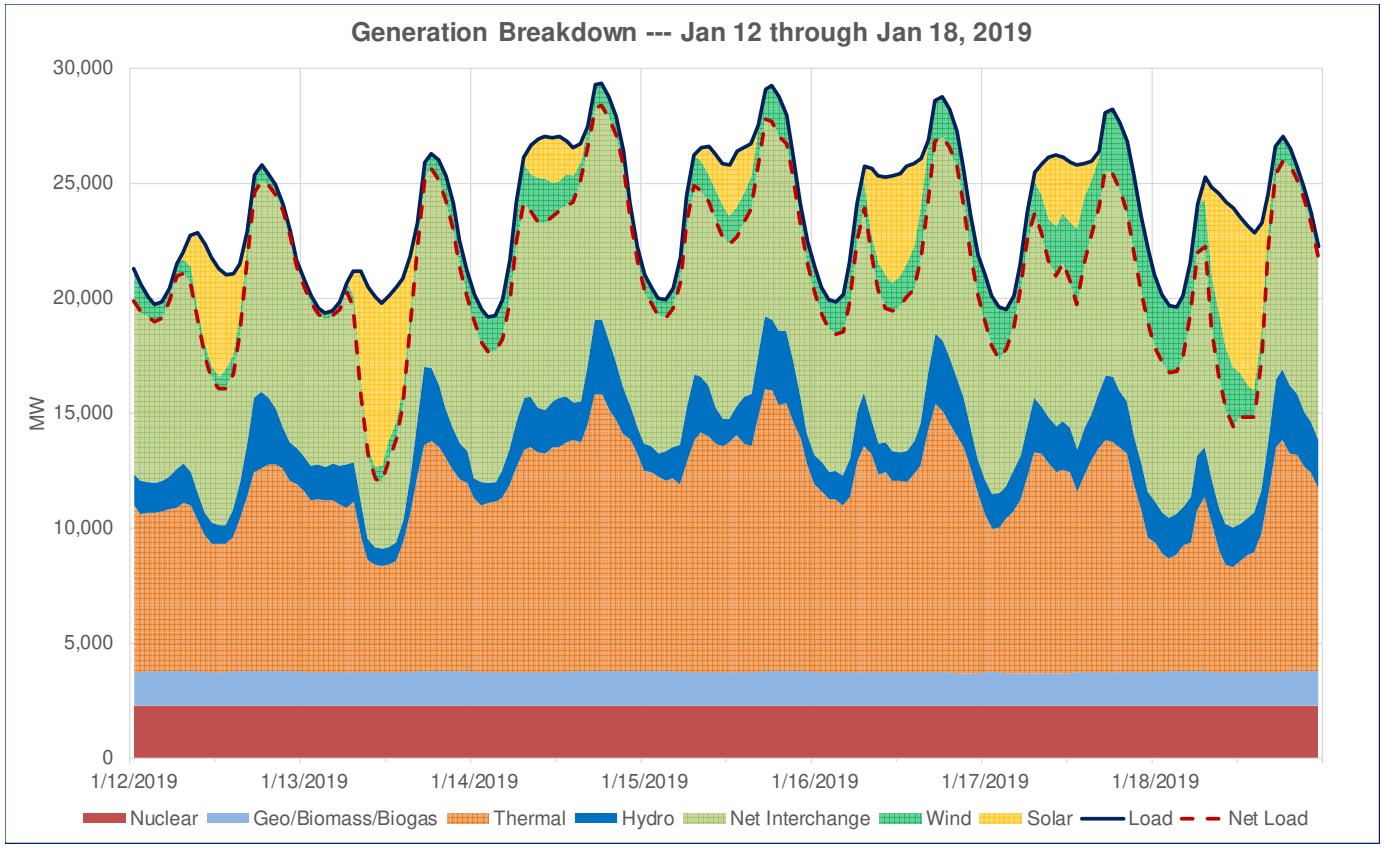
CAISO's current real time operational challenges

- Intra-hour ramps can be greater than ± 6,000 MW in some hours
- Maximum 3-hour ramps greater than 15,000 MW during sunset
- 10-minute variability between ±1,000 MW and ± 1,500 MW
  - Dispatch decisions for the binding 5-minute interval could be off by ± 1,500 MW
- Depleting regulation procured in some hours
- Oversupply conditions continues to increase
- Experiencing control performance challenges during sunrise and sunset and the middle of the day on weekends
- During spring, cannot commit enough gas units on governor control to meet primary frequency response obligation --- especially under hydro spill conditions

Actual net load vs. minimum non-dispatchable resources that's needed for controllability through 2024



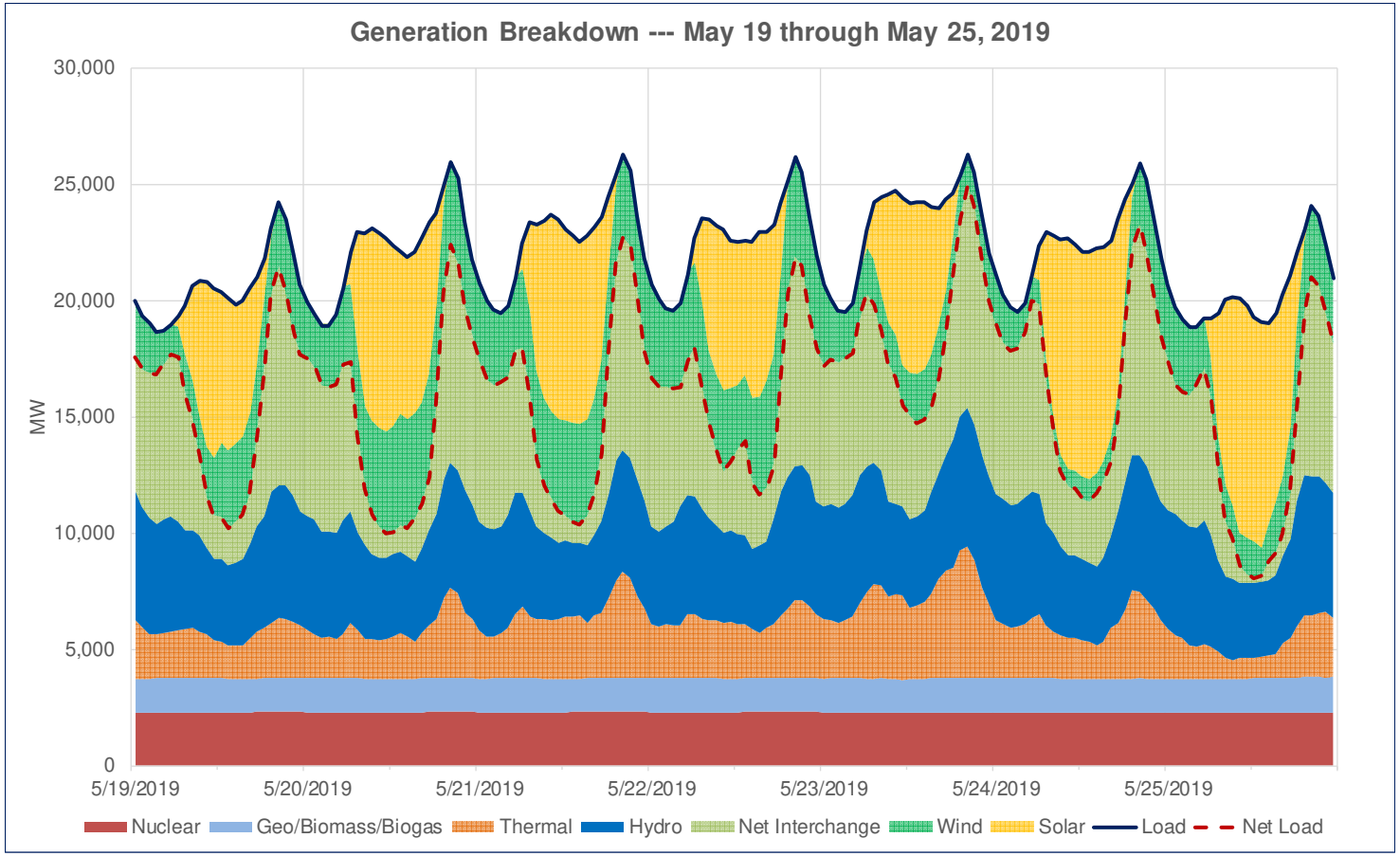
January 14-17, 2019 the hourly solar production was low due to cloud cover while gas gen and imports filled the gap



1/14/2019

- Weather: Cloudy/slight rain
- Maximum net import was 9,820 MW
- Max hourly solar production was 1,970 MW
- Maximum simultaneous wind/solar was about 3,800 MW and occurred during HE11
- Maximum thermal generation was about 12,000 MW

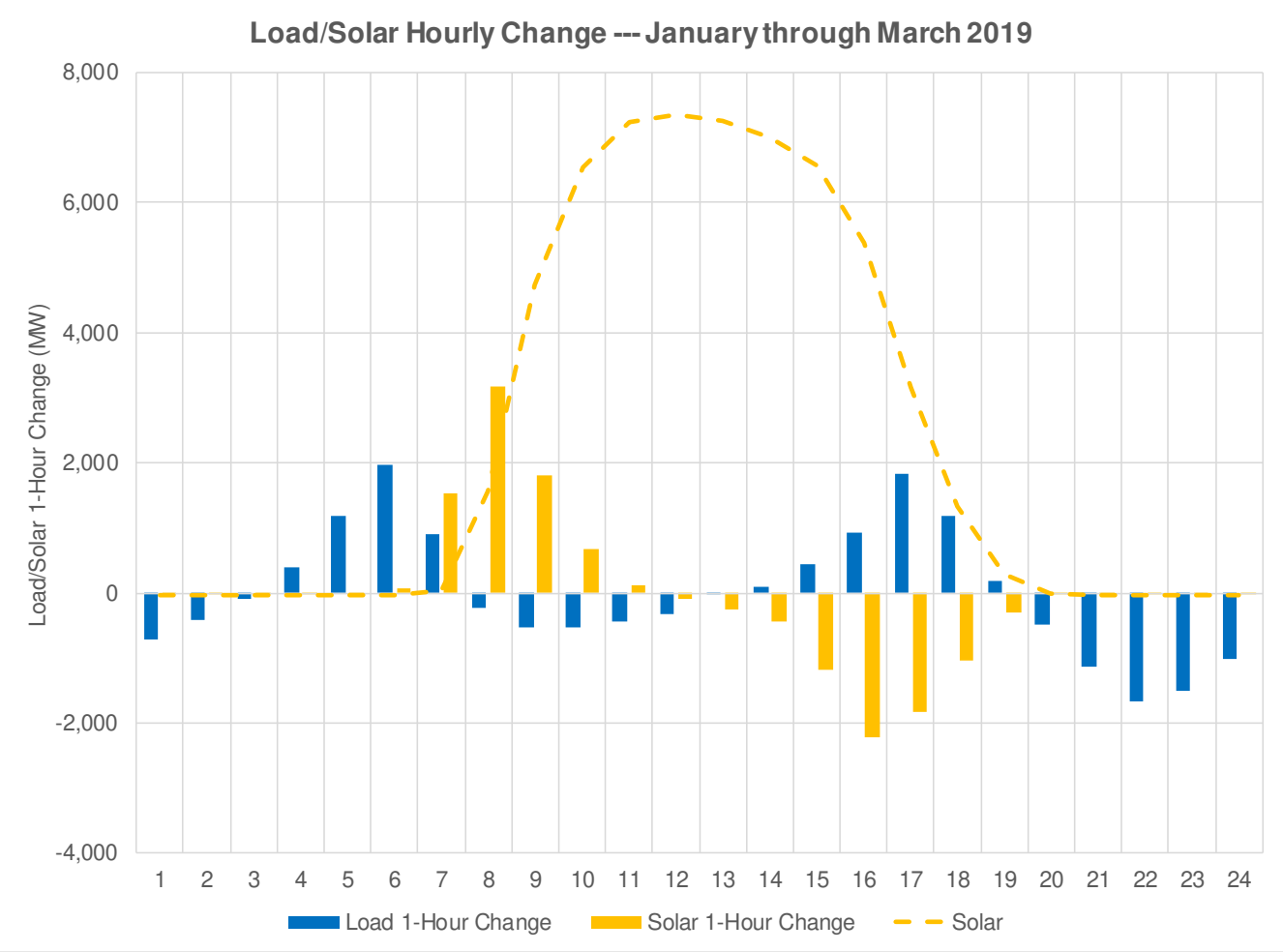
In comparison May 19-25 solar production combined with hydro production required minimum thermal production



During Hydro Spill Conditions

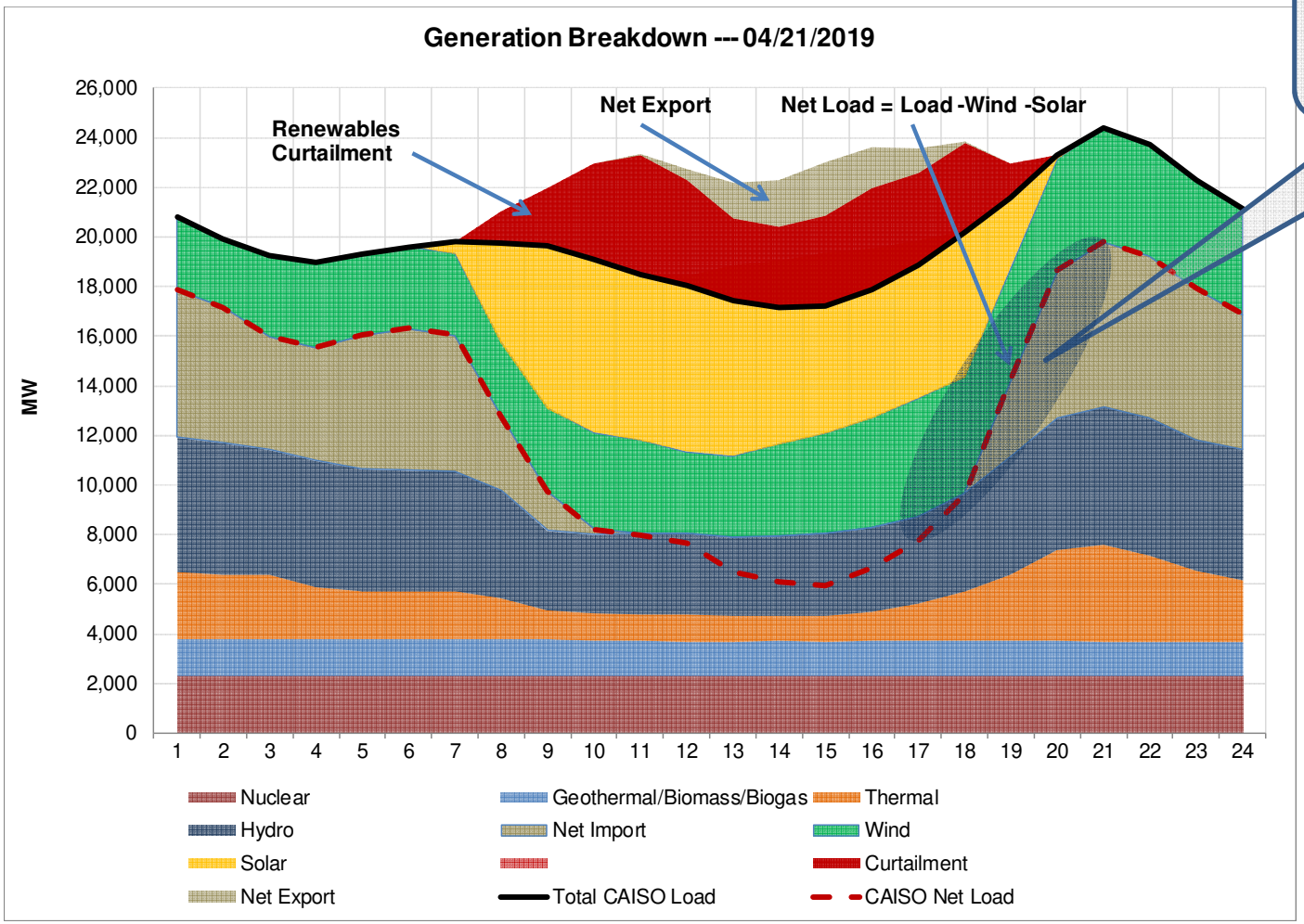
- Rely on gas fleet for most ancillary services
- Typically operate gas fleet at low operating levels to minimize over supply
- Committed gas fleet cannot provide adequate primary frequency response obligation
- Need renewable resources to provide essential grid services

Hourly load and solar change for January through March 2019



- During sunrise, while solar is ramping up, load is still dropping off partly due to roof-top solar PV
- Recommend imposing a maximum ramp rate limit on all new solar resources at 10% of P_{max}/min
- May have to impose a MW/hour limit on aggregated solar production during sunrise due to high ACE and frequency
- During sunset, load is increasing while solar production is decreasing, which drives the 3-hour upward ramping needs

On Sunday April 21, 2019 the CAISO experienced a minimum net of 5,667 MW @ 14:37



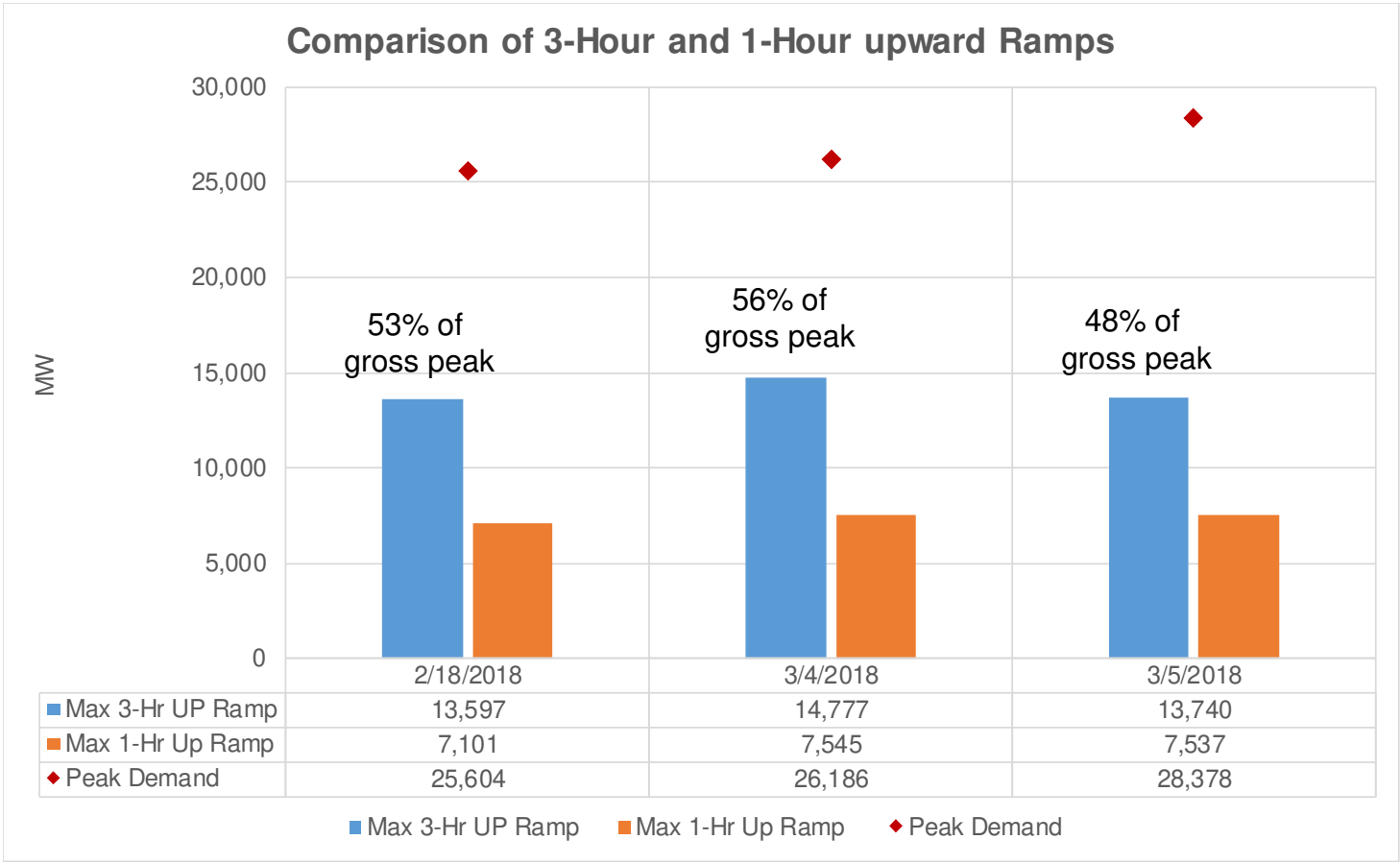
3-hr, 11,355 MW ramp met by:
- Import ~ 64.4%
- Hydro – 15.6%
- Thermal – 20.0%

- Maximum renewable curtailment was 4,789 MW
- Total curtailment of renewables was 31,989 MWh
- Maximum net export was 2,359 MW
- Max EIM export was 4,150 MW
- The CAISO continued to curtail solar during sunset, which helped in reducing the 3-hour upward ramp
- Max simultaneous wind & solar production was 11,598 MW at 14:36

What is the ISO doing?

- Sharing awareness of the how demand is balanced during different conditions
- Assessing ability of the resource fleet and import to meet demand in all periods
- In near-term to mid-term, ensure sufficient gas resources are maintained to meet demand when renewable production ceases
- In long-term, support alternatives to gas resource or overbuilding renewables to meet high demand periods
- Support Time-of-Use rates to incentivize demand to respond to system conditions
- Incentivize renewable resource to provide controllability and essential reliability resources traditional provided by conventional resources

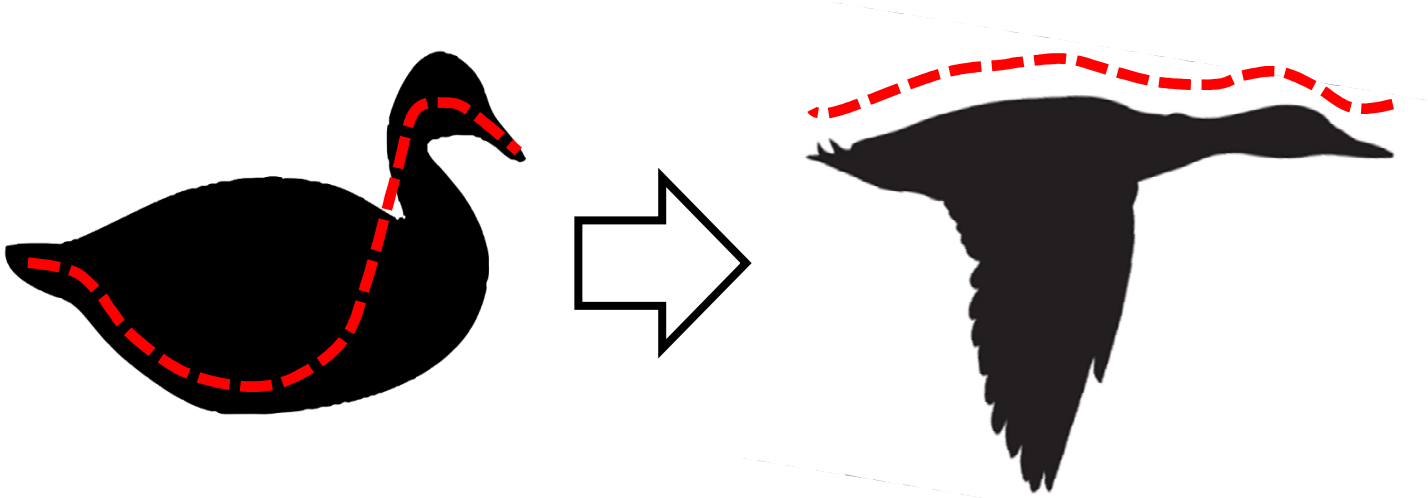
The 3-Hour upward ramps are more than 50% of the daily peak demand, which indicates the need for faster ramping resources



What is the “Duck” telling us?

- Integrating renewables is making significant impact on how we meet mid-day demand
- Management of increased oversupply requires economic bids from all resources, including renewables
- Increasing evening ramp requires flexible capacity to balance supply and demand
- Need additional solutions such as storage, TOU rates, regional collaboration, and using all resources flexibly could help manage increasing oversupply and ramping needs
- Need to maintain sufficient production capacity during periods of low renewable production due to multiple days of cloud cover and low winds
- The volume and speed at which solar resources ramp up is faster than demand is increasing and needs to be managed
- Renewable resources need to follow dispatch instructions similar to other resources

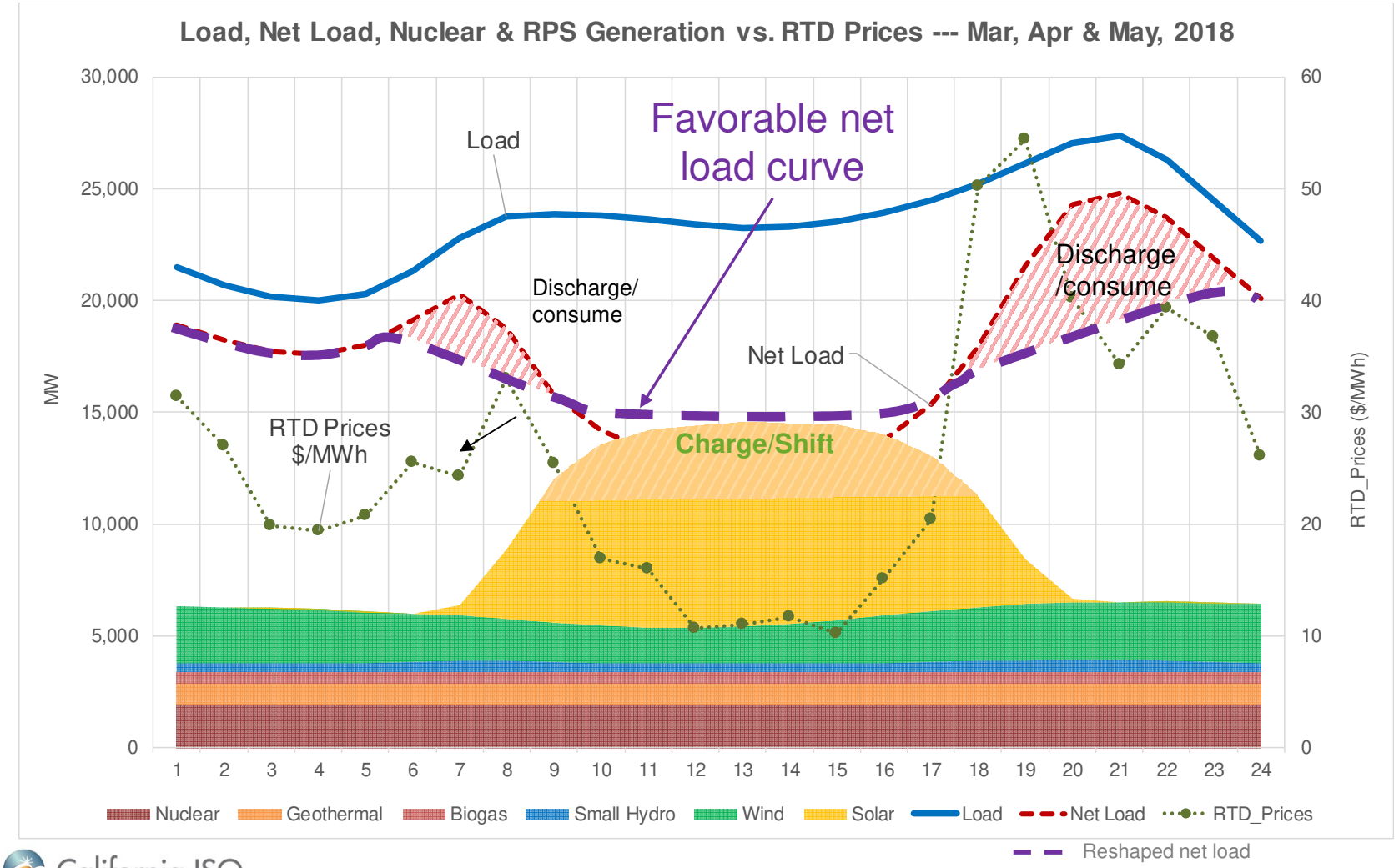
How are we going to ensure our energy future is resilient, sustainable and efficient?



We must make the duck fly!

A healthy grid must counter-act the ill-affects of the sitting “duck curve”

Must leverage all capabilities across the grid to achieve a more favorable/flatter net load shape



What levers must we pull to create a more favorable load shape and operationally sustainable grid?

Shifting

Shaping

Storage – increase the effective participation by energy storage resources.

Western EIM expansion – expand the western Energy Imbalance Market.

Demand response – enable adjustments in consumer demand, both up and down, when warranted by grid conditions.

Regional coordination – offers more diversified set of clean energy resources through a cost effective and reliable regional market.

Time-of-use rates – implement time-of-use rates that match consumption with efficient use of clean energy supplies.

Electric vehicles – incorporate electric vehicle charging systems that are responsive to changing grid conditions.

Renewable portfolio diversity – explore procurement strategies to achieve a more diverse renewable portfolio.

Flexible resources – invest in fast-responding resources that can follow sudden increases and decreases in demand.

Can variable energy resources provide essential reliability services to reliably operate the grid?

- NERC identified three essential reliability services to reliably integrate higher levels of renewable resources
  - Frequency Control
  - Voltage Control
  - Ramping capability or Flexible Capacity
- Test results demonstrated the plant has the capability to provide these essential reliability services
- Advancement in smart inverter technology allows VERs to provide services similar to conventional resources
- VERs with the right operating characteristics are necessary to decarbonize the grid

Actual test results of a 300 MW solar PV plant for regulation, voltage and high and low frequency events